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Promoting On-Farm Water Harvesting and Conservation Techniques for Sustainable Agricultural Production Systems through Capacity Development of Field Extension Officers and Farmers

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Water deficit constitutes a major constraint in crop production generally and rice particularly. Rainfall is the most critical and least predictable among climatic factors, and both the distribution and amount of rainfall during the cropping season are key determinants of crop yields, particularly in areas with less than 2000 mm of annual precipitation such as the Northern Region of Ghana. When torrential rains fall on less porous soils in areas with undulating topography, large amounts of water are lost as runoff from farmlands, resulting in moisture stress at the most critical stages of crop development. Water conservation constitutes one of the greatest challenges to agriculture in developing countries, and simple on-farm water conservation techniques are critical for sustainable agricultural production. To extend the capacities of Agricultural Extension Agents (AEAs) to train farmers in sustainable crop production systems, AEAs were trained in on-farm water harvesting and conservation techniques, and demonstration fields utilizing the on-farm water conservation technique of bunding were established with two rice varieties (Jasmine 85 and Togo Marshall). Field days were organized for farmers and AEAs to observe the use of bunds as a water conservation technique. Mean yield in the treatment plots was 3.51 t/ha as against 2.93 t/ha for control plots (bunding increased paddy yield by 24% in Jasmine 85 and 14% in Togo Marshall). Given the trend of declining annual rainfalls in Ghana, maximizing conservation of runoff rainwater is vital. The prudent utilization of rainwater and conservations practices pays off by maximizing rice production under rainfed conditions. Rainwater harvesting and conservation is therefore emerging as a viable long-term strategy to tackle crop yield losses associated with moisture stress.

Key words: bunding, conservation, demonstration, field day, water harvesting

Introduction

Ghana's agriculture is dominated by small-scale producers who account for about 80% of domestic production. These small-scale farmers, with average farm holdings of about 1.2 ha, utilize very basic technologies in their farming practices. The country's agriculture is characterized by low crop productivity with yields of most crops, including rice, at about 60% of achievable yields (Ministry of Food and Agriculture (MoFA), 2009). This is due primarily to the low fertility status of the soils, which is partly due to low use of fertilizers, use of poor quality seed materials, erratic and declining rainfall, poor delivery of agricultural extension advice, and poor field/agronomic management practices by farmers.

The Northern Region of Ghana receives an average annual rainfall of approx. 1100 mm. However, this falls as torrential rainfall, which when coupled with the poor porosity of soils and undulating topography,

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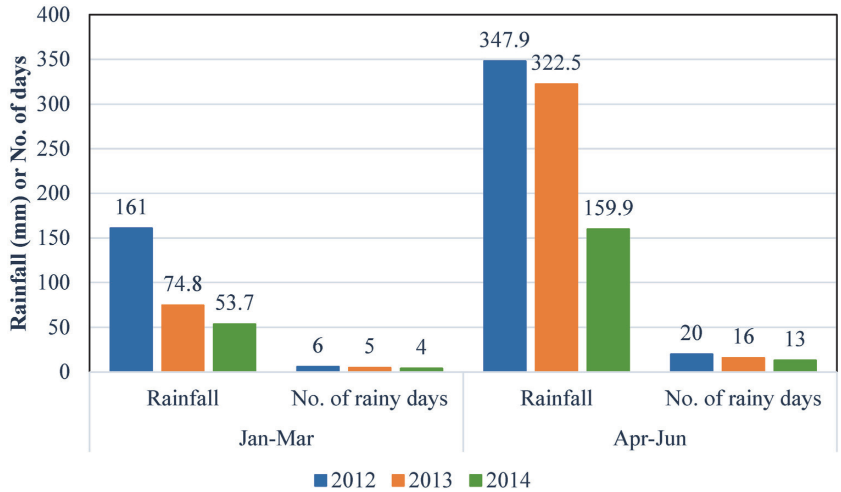

Fig. 1. Rainfall data in the Savelugu Nanton Municipality, "Jan-Mar" and "Apr-Jun" 2012–2014.

results in large amounts of water from rains lost as runoff. Besides yield losses in rice due to moisture stress, this runoff from farmlands facilitates soil degradation through erosion and the subsequent siltation of water bodies as well as loss of fertility in productive farm lands. Rainfall in the Northern Region of Ghana has been in decline for the past three years (2012–2014). Figure 1 shows the rainfall for 1st and 2nd quarters 2012–2014 in the Savelugu Nanton Municipality.

Despite crop productivity at only 60% of potential yields, Ministry of Food and Agriculture (2013) stated that recently (2011–2013), rice production in Ghana has been increasing at an annual rate of 6%, with similar marginal increases in other food staples such as maize, sorghum, cowpeas, yams, and soybeans. Close to 70% of these production increases is due to land expansion, with only 25% being attributed to an increase in productivity per unit area of land. Constraints to rice production across the three agro-ecologies/ecosystems of uplands, hydromorphic lowlands, and rainfed lowlands include drought, weeds, erosion, poor water control, and pests and diseases, with the major constraints being drought, erosion, and poor water management (WARDA, 2001).

Water is becoming an increasingly scarce commodity globally, and global demand for water is increasing daily, not only for agriculture but also for household and industrial purposes. Agarwal and Agarwal (2006) state that by 2025 the world population will hit 8 billion and water will become scarcer, with global farming accounting for 70% of water use, despite the fact that only 17% of farmland is irrigated and provides only an estimated 40% of the world's food.

The problem of water shortages for rainfed agricultural production is due to low rainfall and uneven distribution throughout the season, which makes rainfed agriculture a highly risky enterprise. Rainwater conservation is therefore the only opportunity to reduce the high risk of rice yield losses associated with rainfed agriculture particularly in arid and semi-arid regions of the world. On-farm water conservation and rainwater harvesting, like many other techniques used in today's agricultural sector, are not new. According to Sivanappan (2006), when water harvesting techniques are used for farming, the storage reservoir is the soil itself, unlike when the water is to be used for livestock, supplementary irrigation, or the domestic and industrial sector a storage facility of some kind will have to be constructed to serve as a reservoir. On-farm methods that can be adapted to reduce runoff and improve infiltration to ensure maximum moisture retention for enhancement of production and productivity include earth bunds, vegetative or stone contour barriers, terracing, contour tillage, and tied ridging.

The Asian technique of bunding and levelling land for rice cultivation increases the capacity of the land to retain water by limiting runoff and storing surface and soil water; furthermore, bunding and levelling on sloping land constitutes an advanced method of soil moisture conservation and erosion control (Moorman and Van Breemen, 1978). According to Moorman and Van Breemen (1978), bunding of rice fields and levelling of sloping land brings about a considerable change in the water regime. The overall effect is that water runoff is diminished and more water—whether from a natural source such as precipitation, artificially from irrigation, or both—is retained on or in the soil. Contour soil bunding is the construction of earth banks across the slope to act as barriers to runoff (Adama *et al*., 2006). Bunding and levelling of land for rice cultivation represent a nearly perfect combination of soil and water conservation. This method of water conservation has been an essential part of Asian rice cultivation for centuries, even to the point that steep slopes are often terraced to make water retention/ conservation possible.

As much as 2000 L of water is required to produce just 1 kg of rice (Agarwal and Agarwal, 2006). As a result of rainfall decline, probably due to climate change, and the increasing number of farmers in rice production in the Savelugu Nanton Municipality, there is an urgent need for effective water conservation techniques to efficiently utilize the erratic and uni-modal rainfall that this area receives to address the cycle of rice crop yield losses to ensure sustainable food security and improved livelihoods for the increasing population.

Against this background, there was the need to extend the capacity of Agricultural Extension Agents (AEAs) and rice farmers through training (Fig. 2) in on-farm water conservation techniques to reduce the risk of rice crop failure associated with moistures stress. We conducted training and established demonstration crops with the main goal of enhancing the skills and knowledge base of AEAs and farmers with respect to the on-farm water conservation technique of bunding.

The Specific objectives of the training and demonstrations were to:

1. Identify knowledge gaps of extension officers in on-farm water conservation techniques.
2. Identify and collaborate with a Subject Matter Specialist (SMS) in the field of engineering to train field extension officers on water conservation techniques.
3. Establish a rice crop demonstration plot with collaborating farmers showcasing bunding in rice fields compared to unbunded/flat land in control plots.
4. Organize field days on the demonstration plot for participants to appreciate the possible effects of the bunding technique as a water conservation technique on rice yield.
5. Assess yields from the demonstration fields and share the results with farmers.

Fig. 2. Agricultural Extension Agents (AEA's) undergoing training in on-farm water harvesting and conservation.

Materials and Methods

Identification of knowledge gaps of AEA's

A one day staff meeting was organized involving all 25 Agricultural Extension Agents in the Municipality with the primary objective of identifying their knowledge gaps (strengths and weaknesses) in on-farm water harvesting and conservation techniques. At the end, a catalogue of their knowledge gaps were collated after their filling out some simple pre-training baseline questionnaires designed in collaboration with the Regional Engineer or co- trainer as a resource person. This was done to guide and ensure that the training content was tailor made to meet their needs as extension agents who will afterwards be building the capacity of farmers at the community level.

Identification of External Resource person

The regional Agricultural Engineer was contacted as the subject matter specialist (SMS) for a collaborative approach to design and implement the training programme for the extension agents. Identifying an external resource person was one key activity that needed to be carried out as the intended training/ capacity building area of water harvesting and conservation fell in his area of specialization

Fig. 3 (a). Bunded rice field (Treatment).

Fig. 3 (b). Unbunded/flat rice field (Control).

Establishment of crop Demonstration plots

Two different land configuration systems viz. earth bunding and unbunded/flat land tillage (Figs. 3a and 3b) were established in 2012 to demonstrate two different lowland rice systems under rainfed conditions. Within each of the two land configuration systems, two 10 m × 10 m sub plots were established at random with a programmable calculator in the bunded (treatment) and unbunded (control) plots.

For each variety plot of 0.4 ha, involving treatment and control, all activities such as direct seeding, fertilization and weed management were carried out on the same day. Seed and fertilizer rates were the also same for all plots. Two fields of 0.4 ha each was ploughed and subdivided into 0.2 ha each for treatment and control. Manually, hand hoes were used to constructed bunds 25 cm wide and 25 cm in height as treatments to conserve moisture, with no bunds on the control plots. One 0.4 ha plot was seeded with Jasmine 85 and the other 0.4 ha was planted with Togo Marshall variety. All fields were dibbled and planted at 20 cm × 20 cm (inter and intra) row spacing's at a 50 kg/ha seed rate.

Split-dose fertilization was done in both fields at a rate of 24–12–12 kg/ha of NPK at two weeks after germination by broadcast method and ammonium sulfate top dressing at 10 weeks from planting also by broadcast method. Manual weed control was carried out 2–3 weeks and 5–6 weeks after planting. The area received a unimodal annual rainfall of about 1100 mm in average, in 2012, the year we conducted the current trial the pattern of rainfall started erratically at the beginning of the season in April–June, intensified by mid-July to the end of August which normally registers the highest rainfalls, followed by a sharp decline and finished by mid-September with 1035 mm of rainfall in total for the year with most rainfalls in mid-July to end of August. Maximum daily temperatures over the year averaged 29℃.

Organization of Field days

Field days were organized at land preparation and bunding of treatment plots, planting/seeding, weed control, fertilizer application and maturity/harvesting periods. This was done for farmers and extension agents to interact, share ideas and views and also ask questions for clarification from the resource person/trainer. At crop maturity stage, field days were organized for farmers and AEA's to assess the yield performance for treatment imposed and control plots (Fig. 4), to make informed decisions on the crop technology demonstrated

Assessment of yield from Demonstration plots

At harvest, yield data was taken for each yield plot of 10 m × 10 m subplot by paddy weights and the mean yields from the treatment and control plots of the two varieties computed and compared. Later, the results were showcased at a community forum (Fig. 5) where farmers could use the yield differences as a basis for making decisions on the water harvesting and conservation technique demonstrated.

Results and Discussion

It was noticed after the two day capacity building training of the extension agents that their knowledge and skills in water harvesting and conservation had significantly improved to a better level before the training after a post training questionnaire was also self administered by the extension agents and the outcome compared with the responses from the pre-training questionnaires.

As farmers and the AEA's were taken through the method demonstrations for them to appreciate the methods and procedures in manual bunds construction, so was it important for them to see the effects or results of the technology demonstrated. Data from the established yield plots were taken and the mean yield levels of the treatment and control plots were computed. It was realized that mean yield in the treatment plots was 3.51 t/ha which was substantially higher than 2.93 t/ha in the control plots (Table1) compared to the unbunded /control plots. These results were later shared at a community forum with the participating farmers and other community members. The use of bunding as a water conservation technique increased paddy yield by 24% and 14% respectively in the Jasmine 85 and Togo Marshall varieties (Table 1). These results agree with earlier reports of De Datta (1975) and Abifarin *et al*. (1972) who reported similar findings in lowland rainfed areas in West Africa where rice yields of 0.5–1.8 t/ha could be increased to 1.8–3.6 t/ha with implementation of good agronomic practices. Additionally, Jagvir *et al*. (2006) reported an additional yield of 0.55 to 0.60 t/ha cotton obtained by using ridges and furrows to reduce the amount of rain water runoff compared to an unfurrowed cotton field. Further, they reported that an increase in yield by 20–25% at ridges and furrows system was also noticed at higher doses of fertilizer. Therefore, the technique of soil moisture conservation through bunding and other methods has the potential of increasing moisture content, and thereby yields, even when rainfall is scarce.

Conclusion

In developing countries, rainfall lies at the root of all agriculture, either rainfed or irrigated. Issues relating to water availability and rainfall have gained global attention; however, in developing countries like

Fig. 4. Farmers and AEAs at a field day on the rice demonstration field.

Fig. 5. A community forum discussing the results obtained from the demonstration fields.

Table 1. Effect of bunding on paddy yield in rice.

(t/ha)

Plot	Variety		Mean
	Jasmine 85	Togo Marshall	
Treatment (T)	4.06	2.96	3.51
Control (C)	3.27	2.59	2.93
(T-C) / C * 100	24	14	20

Ghana, lack of expertise, funds, national policies, and public awareness, as well as the need for advocacy, means that little can be done about this problem which requires the input of all stakeholders involved in the agriculture and food security sector.

Maximizing conservation of runoff rainwater and prudent implementation of water conserving techniques pays off by maximizing rice production under rainfed conditions. As the amount of rainfall and the number of rainy days per season is on a decline, the proper harvesting and conservation of soil moisture resources becomes even more vital to reduce the risk of declining rice yields associated with moisture stress, which is increasingly becoming necessary to feed the ever-increasing global population.

Recommendations

In view of the fact that field extension officers of MoFA are the disseminators of improved technologies to farmers, periodic refresher training sessions to upgrade their knowledge and skills level on simple on-farm water conservation techniques should be encouraged and reviewed as and when the need arises to match modern trends of soil water conservation techniques.

In addition to these measures, it is necessary to find means and ways of mainstreaming water conservation techniques into all farming systems to maintain and conserve our soil and water resources for the benefit of both present and future generations.

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